ENHANCED PARTIAL TRANSMIT SEQUENCE TECHNIQUE WITH IMPROVED PARTITIONING AND PHASE FACTOR METHODS FOR ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SYSTEMS

By

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LIST OF ABBREVIATIONS

3GPP	3rd Generation Partnership Project
4G	4th Generation
ACE	Active Constellation Extension
ACI	Adjacent Channel Interference
ADC	Analog-to-Digital Converter
AM	Amplitude Modulation
AP	Adjacent Partitioning
ASK	Amplitude-Shift Keying
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BIP	Blocked Interleaved Partitioning
BIPBR	BIP with Blocked Random Phase Selection
BIPSC	BIP with Smallest Correlation Phase Vector
BRPS	Blocked Random Phase Selection
BW	Bandwidth
CCDF	Complementary Cumulative Distribution Function
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
CF	Clipping and Filtering
CP	Cyclic Prefix
CPU	Central Processing Unit
DAC	Digital-to-Analog Converter
DAB	Digital Audio Broadcasting

DVB	Digital Video Broadcasting
DFT	Discrete Fourier Transform
ETSI	European Telecommunication Standards Institute
FDM	Frequency Division Multiplexing
FFT	Fast Fourier Transform
FM	Frequency Modulation
FPGA	Field Programmable Gate Arrays
FRAT	Finite Radon Transform
FSK	Frequency-Shift Keying
GI	Guard Interval
HF	High Frequency
HIPERLAN	High Performance Radio Local Area Network
HPA	High Power Amplifier
IBO	Input Back Off
ICF	Iterative Clipping & Filtering
ICI	Inter Carrier Interference
IDFT	Inverse Discrete Fourier Transform
IEEE	Institute of Electrical and Electronic Engineers
IFFT	Inverse Fast Fourier Transform
IP	Interleaved Partitioning
ISI	Inter Symbol Interference
I-Q	In phase-Quadric phase
LAN	Local Area Network
LTE	Long Term Evolution
MATLAB	Mathematical Laboratory

MC-CDMA	Multicarrier Code-Division Multiple Access
MCM	Multi-Carrier Modulation
MIMO	Multiple-Input-Multiple-Output
M-PSK	Multilevel Phase Shift Keying
M-QAM	Multilevel Quadrature Amplitude Modulation
OBO	Output Back Off
OOB	Out-of-Band
OFDM	Orthogonal Frequency Division Multiplexing
PA	Power Amplifier
PAPR	Peak-to-Average Power Ratio
$PAPR_0$	Threshold Peak-to-Average Power Ratio
PHY	Physical Layer
PM	Phase Modulation
PRP	Pseudorandom Partitioning
P/S	Parallel to Series Data Converter
PSK	Phase Shift Keying
PTS	Partial Transmit Sequence
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
SCPV	Smallest Correlation Phase Vector
SER	Symbol Error Rate
SI	Side Information
SLM	Selective Mapping
SNR	Signal to Noise Ratio

S/P	Series to Parallel Data Converter
SQNR	Signal to Quantization Noise Ratio
TI	Tone Injection
TR	Tone Reservation
WiMAX	Worldwide Interoperability for Microwave Access
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
WMAN	Wireless Metropolitan Area Network
WPAN	Wireless Personal Area Network
ZP	Zero Padding

LIST OF SYMBOLS

(*)	Complex conjugate operation
$\varphi(r_i)$	Phase factors
φ_i	Rotation angles
τ	Number of times iterations
b_u^v	Phase factor
${}^nC_r$	Number of combinations
dB	Decibel (ratio in log scale)
$d_0 \ldots \ldots d_{z-1}$	Levels for each partition
$\mathrm{E}\{\cdot\}$	Expected value
F	Group of signals
Δf	Sub-carrier spacing
f_k	Center of frequency
f	Frequency
I	Index function
i	Partition number
i^{th}	Index partition
k^{th}	Frequency index
L	Length of adjacent partition
$l_{\tilde{p}}$	Adjacent lengths of original frame
M	Number of sub-blocks
MP	Mid-point
N	Number of subcarriers

N_c	Total number of rotation combinations
n	Discrete time index
n_c	Number of candidate signals
n_d	Number of divisions
n_P	BIP partition in the new frame
$n_{\tilde{P}}$	Adjacent partition in the original frame
n_s	Number of symbols in a sub-blocks
$n_{\widetilde{sb}}$	The number of sub-blocks within each partition
P_i	Corresponging disjoint partitions
$\acute{P}_i$	Variable length disjoint subsets of OFDM frame
P^{th}	Element of the group
q	Symbol number within a sub-block
r	Sub-block number within a partition
r^{th}	Sub-block from each partition
Sb_{ir}	sub-blocks within adjacent partition
T	Total OFDM symbol duration
T_s	Symbol duration
T_b	Bit duration
U	Number of candidate signals
V	Number of sub-blocks or clusters
w_i	Rotation factor
X	Data block in frequency domain (original frame)
$\hat{X}$	New frame of interleaving of the sub-blocks
X_k	Input data symbols (the modulated data at k^{th} subcarrier)

X_m	Sub-blocks Vectors
x_m	Block of time domain
$x_i(n)$	Time domain signals
$x_i^{r_i}(n)$	Phase rotated sequences of time domain signals
$\tilde{x}_n$	Transmit signal candidate
x_n	OFDM signal at the discrete time
z	Number of phase rotation levels for each partition
z^{n_P}	Total number of rotation combinations

Teknik Jujukan Pancaran Separa Dipertingkat dengan Kaedah Faktor Fasa dan Pemetakan Diperbaiki untuk - Sistem Pemultipleksan Pembahagian Frekuensi Ortogon

ABSTRAK

Pemultipleksan Pembahagian Frekuensi Ortogon (*Orthogonal Frequency Division Multiplexing*, OFDM)) merupakan suatu teknologi penting ─ yang membolehkan pemancaran pada kadar data yang tinggi. Walau bagaimanapun, masalah utama-sistem OFDM adalah nisbah kuasa puncak-kepada-purata (*peak-to-average power ratio*, PAPR) yang tinggi pada isyarat OFDM. PAPR yang tinggi menyebabkan penguat kuasa pemancar (*power transmitter,* PA) menjadi tepu, dan mengakibatkan herotan tak linear. Dalam usaha meningkatkan prestasi sistem OFDM, PAPR perlu secara signifikan dikurangkan pada kekompleksan/kerumitan pengiraan yang lebih rendah. Bermotivasikan keperluan teknik pengurangan PAPR yang efisien berkaitan sistem pembawa berbilang, seperti OFDM, kajian ini meneliti teknik pengurangan PAPR terkini dan mencadangkan teknik pemprosesan isyarat baharu yang mampu mencapai PAPR minimum pada kekompleksan pengiraan yang lebih rendah bagi parameter sistem yang diberi, yang serasi dengan piawaian atau standard yang sesuai. Tesis ini mencadangkan satu skema baru yang fleksibel dan praktikal bagi mengurangkan PAPR, berdasarkan teknik jujukan pancaran separa (*partial transmit sequences*, PTS), yang merupakan pendekatan berkebarangkalian yang terkenal bagi masalah PAPR. Pendekatan ini mengurangkan PAPR tanpa sebarang pengurangan prestasi yang signifikan impak yang buruk, atau perubahan pada sistem. Pendekatan yang dicadangkan ini menghapuskan kelemahan teknik PTS semasa, iaitu kekompleksan pelaksanaan yang tinggi bagi mencapai pengurangan PAPR yang signifikan. Dalam tesis ini, tiga kaedah dicadangkan untuk mencapai PAPR minimum dengan kekompleksan pengiraan yang rendah dalam sistem OFDM. Pendekatan ini meningkatkan kedua-dua skema pemetakan dan putaran fasa dalam rangka kerja PTS bagi meminimumkan PAPR pada kekompleksan pelaksanaan yang lebih rendah. Prestasi pendekatan dinilai melalui pengiraan PAPR yang mencapai pendekatan ini dan membandingkannya dengan PAPR yang direalisasikan oleh skema PTS tradisional Berikut adalah sumbangan utama kajian ini. Pertama, tesis ini telah mencadangkan satu kaedah pemetakan PTS yang baharu, iaitu Pemetakan Antara Lembar Terblok (*Blocked Interleaved Partitioning*, BIP), yang mendorong kepada prestasi pengurangan PAPR yang lebih baik. Kedua, Vektor Fasa Kolerasi Terkecil (*Smallest Correlation Phase Vector*, SCPV) dan Pemilihan Fasa Rawak Terblok (*Blocked Random Phase Selection,* BRPS) dicadangkan bagi menentukan putaran fasa optimum. Gabungan daripada pemetakan yang dicadangkan dan skema putaran fasa terhasil dalam dua skema pengurangan PAPR, yang dinilai sebagai BIPSC-PTS dan BIPBR-PTS. Pendekatan ini secara signifikan mengurangkan PAPR pada sistem dan pada masa yang sama merendahkan kekompleksan pengiraan. Prestasi algoritma yang dicadangkan telah disahkan melalui simulasi komputer. Keputusan menunjukkan bahawa kaedah yang dicadangkan berjaya meningkatkan prestasi sistem OFDM berbanding dengan sistem semasa. Skema yang dicadangkan secara signifikan telah mengurangkan PAPR pada kadar kekompleksan pengiraan yang rendah. Analisis perbandingan tanda aras terhadap kerja yang diterbitkan menunjukkan bahawa kaedah yang dicadangkan BIPSC-PTS dan

BIPBR-PTS mengatasi kerja yang diterbitkan dengan penambahbaikan 29.7% and 22.9% masing-masing. Di samping itu, tanda aras masa pengiraan menunjukkan bahawa kedua-dua kaedah yang dicadangkan berjaya mengurangkan keperluan masa CPU bagi carian putaran fasa melalui faktor 78.5 dan 15.7 masing-masing dibandingkan dengan PTS tradisional.

Enhanced Partial Transmit Sequence Technique with Improved Partitioning and Phase Factor Methods for Orthogonal Frequency Division Multiplexing Systems

ABSTRACT

Orthogonal Frequency-Division Multiplexing (OFDM) is an important technology that enables transmission at high data rates. However, a major problem of OFDM systems is the high peak-to-average power ratio (PAPR) of OFDM signals. High PAPR drives the transmitter power amplifier (PA) into saturation, and causes nonlinear distortions. In order to improve the performance of the OFDM systems, PAPR should be significantly reduced at low computational complexities. Motivated by the requirement of efficient PAPR reduction techniques associated with multi-carrier systems, such as OFDM, this research explores the state-of-the-art PAPR reduction techniques and proposes new signal processing techniques that can achieve a minimum PAPR at lower computational complexities for given system parameters that are compatible with the appropriate standards. This thesis proposes a novel flexible and practical scheme for PAPR reduction, based on partial transmit sequence (PTS) technique, which is a well known probabilistic approach to the PAPR problem. This approach decreases the PAPR without any significant performance loss, adverse impact, or changes to the system. The proposed approach eliminates the known drawback of current PTS techniques, namely the high implementation complexity to achieve a significant PAPR reduction. In this thesis, three methods have been proposed to realize minimal PAPR with low computational complexity in an OFDM system. These approaches enhance both partitioning and phase rotation schemes within the PTS framework in order to minimize PAPR at lower computational complexities. The performances of the approaches were evaluated via computation of PAPR achieving these approaches and comparing them with the PAPR realized by traditional PTS schemes. The following are the principal contributions of this thesis. First, a new PTS partitioning method, namely the Blocked Interleaved Partitioning (BIP), which leads to better PAPR reduction performance, is proposed. Second, the Smallest Correlation Phase Vector (SCPV) and Blocked Random Phase Selection (BRPS) are proposed to determination the optimal phase rotations. Combination of proposed partitioning and phase rotation schemes resulted in two proposed PAPR reduction schemes namely BIPSC-PTS and BIPBR-PTS respectively. These approaches significantly reduce the PAPR of the system and simultaneously lower computational complexities. The performance of the proposed algorithms was verified via computer simulations. The results show that the proposed methods did improve the performance of the OFDM system over the current ones. The proposed schemes significantly lowered PAPR at lower computational complexities. Benchmarked comparative analysis against the latest published work revealed that the proposed methods BIPSC-PTS and BIPBR-PTS outperformed the published work with 29.7% and 22.9% improvements respectively. Also, the benchmarking of computational time showed that these two proposed methods reduced the requirement of CPU time for phase rotation searching by factors of 78.5 and 15.7, respectively compared to traditional PTS.